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SUBJECT Comments on L Landau's Work in Low Temperature Physics

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1. The Soviet scientist, L D Landau, is one of the world's leading theoretical physicists. His interests are varied, and all of his scientific work is interesting. However, I have a firsthand knowledge only of his research in low temperature physics. An original and intuitive thinker, he has derived his theories in low temperature physics through clever, qualitative, phenomenological assumptions, rather than using the detailed proofs required in the orthodox development of new theories. This approach has often exasperated Western physicists, many of whom have been critical of his methods. Nonetheless, his theories have usually been substantiated by scientists who have worked out the details of his theories, and it is now generally realized that Landau can produce sound theories without detailed proof. He has been active in the following three major divisions of low temperature physics:

   a. Superconductivity
   b. Liquid helium
   c. Magnetism

<u>Theory of Superconductivity</u>

2. An example of Landau's post World War II work on superconductivity is a paper titled "On the Theory of Superconductivity" written with V L Ginzburg, published in the Zhur Eksper i Teoret Fiz, 20, 12 (1950) pp 1064-82. David Shoenburg, a physicist at Cambridge University, sent me his English translation of the article. I consider this paper to be important. It presents a new theory of the relationship of a magnetic field to the behavior of a superconductor. It is deeper than existing theories in that it is close to fundamentals. Although not yet the final answer, it is an excellent phenomenological picture of the surface energy between a metal

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in the superconducting and in the normal phase. It is particularly helpful in understanding the behavior of phase transition, and accounts, at least qualitatively, for a lot of complicated phenomena like the metastability of the normal phase below critical field strength, and the shape of the magnetization curve for superconductors of small dimension.

3. In the above paper, Landau introduces a new characteristic parameter, which he terms Ψ, in the description of a superconductor. He gives a physical interpretation of this parameter or an "ordering" parameter, and assumes an additional term in the free energy of the superconducting phase in a magnetic field which depends on Ψ :

$$F_{SH} = F_{SO} + \frac{H^2}{8\pi} + \frac{1}{2M}\underbrace{\left| -i\hbar\nabla\Psi - \frac{e}{c}A\Psi \right|^2}_{\text{NEW TERM}}$$

H = MAGNETIC FIELD
A = VECTOR POTENTIAL
F_{SO} = FREE ENERGY IN ABSENCE OF FIELD

This leads to a change in the basic electrodynamic equations describing a superconductor, originally due to F. London at Duke University. Landau derives

$$\frac{d^2A}{dz^2} - \frac{4\pi e^2}{mc^2}\Psi A = 0$$

which differs from London's equation because Ψ is now a variable. A new equation is given to determine Ψ , namely

$$\frac{d^2\Psi}{d^2z^2} + \frac{2m}{\hbar^2}|\alpha|\left(1 - \frac{e^2}{2mc^2|\alpha|}A^2\right)\Psi - \frac{2m}{\hbar^2}\beta\Psi^3 = 0$$

An expression for the surface energy between normal and superconducting phases can now be obtained in terms of Ψ :

$$\sigma_{ns} = \int\left\{\alpha\Psi^2 + \beta\frac{\Psi^4}{2} + \frac{\alpha^2}{2\beta} + \frac{\hbar^2}{2m}\left(\frac{d\Psi}{dz}\right)^2 + \frac{e^2}{2mc^2}A^2\Psi^2 + \frac{H^2}{8\pi} - \frac{H_{RM}H}{4\pi}\right\}dz$$

This can then be used to obtain experimentally verifiable results for the critical field of thin films, and magnetization of thin film.

4. Other Soviet physicists have followed up on Landau's work, and Ginzburg has written a paper titled "The Present State of the Theory of Superconductivity" in Uspehki Fiz Nauk, 42, 2 (1950) pp 169-219. I first noticed this paper in an East German publication, the name of which I do not recall. This paper, which is well written, is an international survey of work which has been done on superconductors. In a phenomonological way Ginzburg introduces the temperature gradient and chemical potential gradients in the normal and supercurrent equations, and heat conductivity in the two-fluid model.

5. Many Western physicists have been influenced by Landau's work. J Bardeen at the University of Illinois, and A B Pippard at Cambridge University have similar ideas. Several US scientists have referred to Landau's 1950 paper on superconductivity in their work. For example, The Physical Review, 88, 2, October 1952, has an article titled "The Free Energies and Phase Transition of a Cylindrical Superconductor". The author refers to Landau's 1950 paper on superconductivity which introduced a variable order parameter, essentially Λ or λ.

Work in Liquid Helium

6. In 1941 Landau developed an important theory on the hydrodynamics of liquid helium using quantum mechanics. A preliminary article calling attention to this theory appeared in The Physical Review, 60, August 1941, p 356, [illegible]

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"Theory of the Superfluidity of Helium II". The main article was published in the J Physics, USSR, 5, 81 (1941). Some scientists are critical of certain parts of his theory. I have an open mind toward it, and I find it to be helpful in my own work. Conclusions can be made on the flow of liquid helium, and on the propagation of sound waves in liquid helium. Another aspect of the theory is the proposal of a particular form for the spectrum of elementary excitations in liquid helium. In developing this theory, Landau demonstrated his unique technique of successfully expressing his ideas in a qualitative manner with many assumptions.

Magnetism

7. Landau has done important work on dimagnetism of metals according to the quantum theory. One of his first papers was in Zeits für Phys 64 (1930) p 629. Later, in 1939, he published a paper explaining the De Haas-Van Alphen effect, a periodic variation of the dimagnetic susceptibility with field strength.

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